Review

# The efficacy of digital media tools to promote a healthy diet in children: A systematic review of intervention studies

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**Abstract.** *Background and aim:* Proper nutrition during childhood is essential to ensure healthy growth of children and good health in adulthood. Different types of interventions have been suggested to promote nutritional health in children. This systematic review aims to summarize the available evidence from experimental studies on the efficacy of digital media tools for the promotion of a healthy diet in school-aged children. *Methods:* According to PRISMA guidelines, a literature search was conducted in the three main electronic databases (PubMed/Medline, Embase e Scopus) until April 2022. We included all experimental studies assessing the effectiveness of digital media tools for nutritional health promotion in children from 5 to 12 years of age. *Results:* Nine studies were included in our analysis, mostly carried out in school settings. Nine of them investigated the use of a videogame, while two studies involved watching a video. Almost all the interventions tested were effective in promoting a healthy diet in school-aged children in the short term, regardless of the type of intervention and age of the children involved. A statistically significant increase was observed post-intervention in all studies, both in knowledge of food groups and food frequencies, and in practices (i.e. the amount of fruit and vegetables servings consumed per meal), although the effect faded over time (when follow-up data were available). One study, carried out among selected sample of overweight children, showed no effect in eating behaviour following the intervention. *Conclusions:* Digital media tools can be used to effectively implement health promotion interventions to improve knowledge and adherence to healthy diets in school-aged children. Further studies are needed to assess the long-term effectiveness of these interventions. (www.actabiomedica.it)

**Key words:** Children, nutrition, digital tools

## Introduction

Following a healthy diet throughout the life course is extremely important to promote health and to prevent noncommunicable diseases, such as type II diabetes, heart disease, stroke and cancer (1). In children, especially in the first two years of life, a nutritionally adequate diet is fundamental to allow optimal growth and improve cognitive development (2). The eating behaviors acquired in early childhood have shown to deeply influence dietary patterns in adulthood (3). Therefore it is important to expose children to healthy food choices from an early age and teach them the basis of nutrition, in order to increase their knowledge and set the grounds for a healthy diet during adulthood.

Childhood overweight and obesity represent a growing problem in our society, with an estimated 38.2 million children under the age of 5 years being overweight or obese in 2019 worldwide (4). In the United States, more than one fifth of children aged 6- to 11-years old are obese (5). Data from European countries have shown that about 20% of elementary school children are overweight and about 7.5% are obese (6). Given the impact of childhood overweight and obesity on the future health of children, it becomes necessary to develop strategies and intervene through lifestyle modifications at the earliest time possible.

Digital media, namely all the communication media that are created and delivered in machine-readable format through audio and visual material (7,8), have been widely exploited for teaching purposes (9,10), either in addition to teacher-led frontal lectures and educational material, or as the sole teaching resource. In particular, as several studies have shown, there is huge potential for digital technologies to support health promotion and prevention (11). The use of information and communication technologies has grown exponentially over the last decade, leading to changes both in the dissemination and in the access to health information among healthcare providers, citizens and mass media (12).

The use of digital tools to educate about health issues in children has been studied for several years, and has been shown to encourage participation and motivation in learning activities, among adolescents (13) and younger children (14). In particular, educational videogames (games that have the purpose of education) have been increasingly used for health promotion in school-aged children (15–17) as they represent an attractive and familiar tool, yet filled with educational contents. Audio-visual material is already being used in many countries to broadcast information campaigns on the benefits of immunization with vaccines (18).

This systematic review aims to determine the efficacy of digital interventions to promote a healthy diet among children.

## Methods

This systematic review was conducted following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement for reporting (19). The methods were registered in advance in the Prospective Register of Systematic Reviews (PROSPERO), number CRD42022325554.

The literature search was performed using a combined search strategy consisting of free-text terms and MeSH headings for the topics of health promotion, nutrition, audio-visual tools, and children. The complete search strategy is available in the Supplementary material (Appendix 1). The strategy was first developed for the PubMed database and subsequently adapted for the others (Scopus, Embase). To retrieve further possible relevant articles, the authors cross-referenced the citation lists of the retrieved studies. Searches were performed up to April 2022, without any time restriction.

We included studies that: (i) had an experimental study design; (ii) evaluated the efficacy of interventions with audio/visual tools aimed at promoting a healthy diet in children; (iii) involved children between 5 and 12 years of age; (iv) were available in full-text; (v) were published in English. Records that met the following criteria were excluded: (i) studies without measures of the outcomes of interest; (ii) studies that did not consider the impact of digital tools; (iii) works published as narrative review, editorial, or letter to editor. Primary outcomes of interest were any indicators of knowledge, attitudes and behaviors in children regarding nutrition and eating habits.

Two reviewers (FA, GD) independently screened records to identify relevant reports in a two-step procedure; a first screening was done based on title and abstract, while complete texts were retrieved for the second screening. Data from the included studies were extracted and entered in a table developed by the authors. For each article, the following baseline characteristics were extracted: first author's last name, country and year of study implementation, population and sample size, age range of participants, study setting, study design, outcomes considered, measures of outcomes and characteristics of the intervention (digital tool used, control and experimental type of intervention, follow-up time, assessment tools and timing of assessments).

A descriptive analysis of the available data was performed, pooling quantitative data on the effect of the intervention in a separate table. Quantitative analysis of the effect of interventions was performed comparing pre- and post- intervention data from each study. Due to the high heterogeneity of outcome measures, it was not possible to carry out meta-analysis.

## Results

A total of 1305 articles were retrieved. After duplicate removal (352 titles) and a preliminary screening of title and abstract, a total of 101 articles were consulted in full. Of these 101 articles, most (32) were excluded for the age range as they either included participants younger than 5 or older than 12 years of age without stratification. Another important reason for exclusion was the study design (14) that was either not a clinical trial or did not have pre- and post- intervention comparison to evaluate its efficacy. Eight studies were excluded because the intervention was not based on digital tools. At the end of the selection process (available in Figure 1), nine articles were included in this systematic review.

Complete studies' characteristics are reported in Table 1. All the included reports were experimental studies published between 2004 and 2021 in Europe (20), North America (21–26), and Asia (27,28). The smallest sample size consisted of 73 children (23), and the largest included 1859 participants (26). Most studies were conducted in school settings, except for one that was carried out at home by participants that were selected among overweight and obese children attending a clinic (21). Considering the participants' characteristics, the proportion of girls ranged between 38% and 53%, although two studies did not report it. The type of intervention used in most studies was a digital game (7), while two were videos (a peer modelling video and a cartoon, respectively). The control interventions were either no intervention (78%) or the use of a tool that was similar to the experimental branch, but without educational purpose (22%). The primary outcomes measured were knowledge (44%), practice (78%) and attitude (22%), either alone or as a combination of the three. The main endpoints were: i) servings of fruit and vegetables consumption by meal, ii) knowledge on food groups and food frequencies, iii) motivation and self-efficacy to eat fruit and vegetables; iv) Body Mass Index (BMI), fasting insulin, skin carotenoids concentration. Different assessment methods were used in the included studies: researchers directly assessed the outcomes of interest

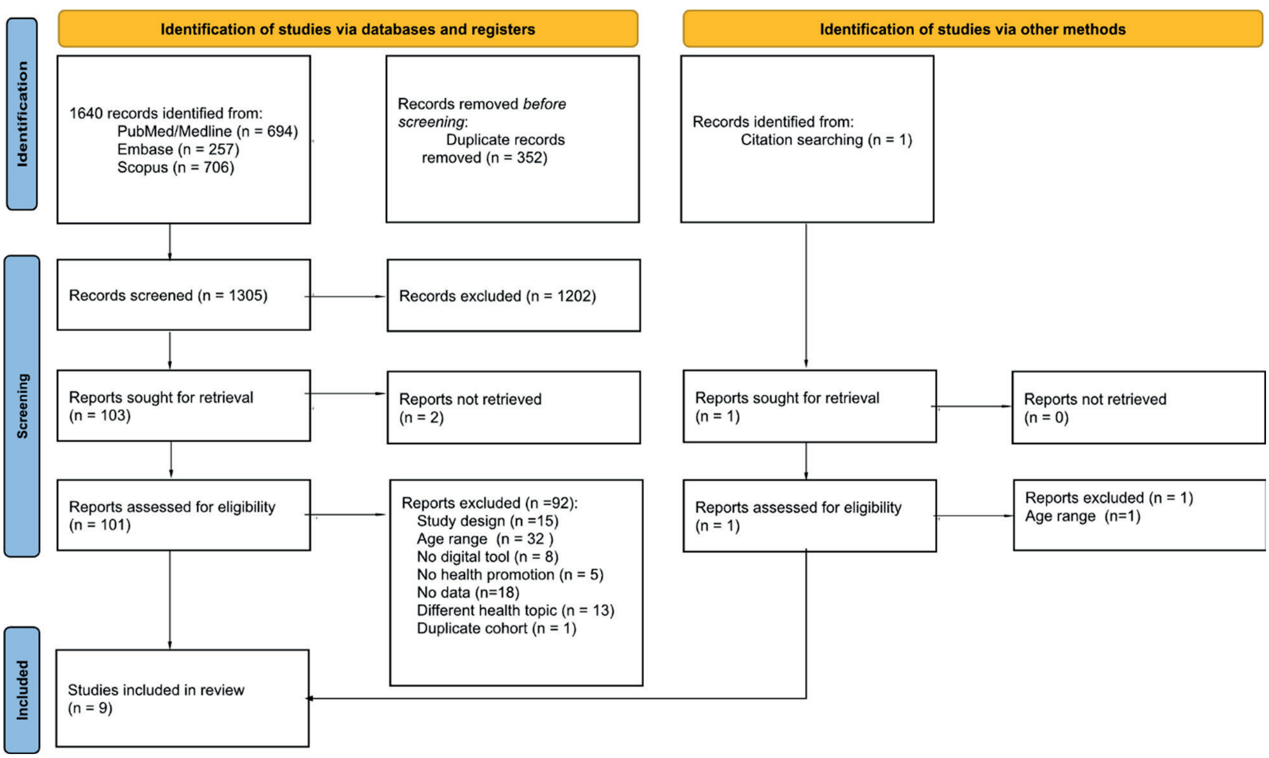


**Figure 1.** PRISMA 2020 flow diagram for new systematic reviews which included searches of databases, registers and other sources.

**Table 1.** Main characteristics of the included studies.

| N | First Author, year | Country | Population | Sample size (%girls) | Age range *years* | Study setting | Study design | Outcomes considered | Outcome measure | Intervention | Control | Follow up time | Digital tool used | Assessment tool and timing |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Baranowski, 2019 (21) | USA | Overweight children | 145 (40%) | 10-12 | Home | RCT | Practice | Primary outcome: fasting insulin. Secondary outcomes: BMI, fruit, vegetable and sweetened beverage intakes, physical activity. | Children played two role-playing videogames (*Escape from Diab* and *Nanoswarm: Invasion from Inner Space*) with nine sessions (each episode/session lasting ~60 minutes). Two storylines attempted to immerse players and used ethnically diverse characters to model desired behaviors. Children played the videogames at home, with no deadlines and no guidance provided to parents. | No intervention | 2 months | Digital game | Data were collected at baseline, post-intervention (3 months) and at follow up (2 months. Self-reported questionnaires were used for demographics, FV and food frequency intake; gameplay data collected over the Internet; blood and anthropometric assessments by trained staff; physical activity measured through accelerometers worn on the body. |
| 2 | Bell, 2018 (22) | USA | Children attending school | 180 (n/a) | 9 - 12 | Elementary school | Quasi-experimental intervention | Knowledge and practice | Preference for and motivation to eat FV; self-efficacy to cook and eat fruits and vegetables; and dietary intake of FV. | Participants played Virtual Sprouts (a game includes a series of cooking and gardening activities) on tablets for 1 hour a week, and received teaching for 1 hour a week, in addition to one family home activity per week for 3 weeks. | No intervention | No follow up | Digital game | Self-administered questionnaire at baseline and after the intervention (3 weeks), plus a food recognition and taste test |

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| 3 | Froome, 2020 (23) | Canada | Children attending school | 73 (38 %) | 8 - 10 | Summer day camps for children | RCT (Single-blinded, parallel) | Knowledge | Primary outcome: overall nutrition knowledge. Secondary outcomes: knowledge on Drinks, Whole Grain Foods, Vegetables and Fruits, and Protein Foods. | 5 sessions of 15 minutes playing with *Foodbot Factory* mobile application (an evidence-based serious game) | 5 sessions of 15 minutes playing with an app called "My Salad Shop Bar" | No follow up | Digital game | Self-administered questionnaire (Nutrition Attitudes and Knowledge) at baseline and day 5. |
| 4 | Gan, 2019 (27) | Philippines | Children attending school | 360 (52%) | 7 – 10 | Elementary school | RCT (class cluster randomization) | Knowledge | Food groups and food frequency knowledge scores | Healthy Foodie nutrition game (25-40 minutes), composed of 2 parts: Part 1 was about the 3 basic food groups: go (carbohydrate-rich), grow (protein-rich) and glow (vitamins and minerals rich) and the Filipino food plate. Part 2 was focused on food frequencies and the food pyramid. | No intervention | No follow up | Digital game | Self-administered questionnaire (30 min) at baseline and day 7 |
| 5 | Horne, 2004 (20) | UK | Children attending school | 749 (n/a) | 5 - 11 | Elementary School | RCT (school randomization) | Practice | Number of servings of fruit and vegetables at lunchtime and snacktime | Peer modeling videos (Food Dudes), 6-minutes long, showing 4 kids eating fruit and vegetables to fight and win the enemies, the "Junk Punk"; children were given Food Dudes customized items as reward during the first phase and received letters from the Food Dudes as encouragement. Children were given a homepack (instructions and charts) to encourage healthy eating at home too. | No intervention | 4 months | Video | Direct observation: at baseline (12 days), during intervention (16 days) and the last 8 days of maintenance (4 months follow up); parental recall for consumption at home (for 5 days during the first week of baseline and the last of intervention) |

(*Continued*)

**Table 1.** Main characteristics of the included studies. (*Continued*)

| N | First Author, year | Country | Population | Sample size (%girls) | Age range *years* | Study setting | Study design | Outcomes considered | Outcome measure | Intervention | Control | Follow up time | Digital tool used | Assessment tool and timing |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 6 | Sharma, 2015 (24) | USA | Children attending school | 94 (42.9%) | 9 - 11 | Elementary school | Quasi experimental study design with group-randomization | Knowledge, practice and attitude | Intake of fruits, vegetables, fiber, fat, and sugars, nutrition and physical activity knowledge, self-efficacy, attitude, and computer learning attitude. | Playing *Quest to Lava Mountain* videogame for a minimum of 90 min/week for 6 weeks during their regular computer instruction time at the school computer lab or as part of their afterschool program located within the elementary school. | No intervention | No follow up | Digital game | Self-report surveys to obtain data on child behavior and psychosocial factors at baseline and post-tintervention. Direct measurement of child height and weight was carried out by trained staff; dietary intake was evaluated through 24-hours dietary recalls, via telephone or directly. |
| 7 | Thompson, 2015 (25) | USA | Children attending school | 387 (53%) | 9 – 11 | Elementary school | RCT (Four-groups) | Practice | Number of FV servings consumed at lunch | 10-episode, online videogame presented to different groups: The "Action" group set a FV goal and then created an action plan (i.e., implementation intention) specifying how (i.e., who, what, when) they would meet the goal. The "Coping" group set a goal to eat more FV and created a coping plan (i.e., implementation intention) that identified a potential barrier that might keep them from meeting their goal. Children assigned to the "Both" group set a goal to eat FV, then created both action and coping plans. | Children played the game but only set a goal to eat FV. | 3 months | Digital game | Dietitian-assisted telephone recalls at baseline, immediate post-intervention, 3 months post-intervention |

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| 8 | Wang, 2017 (28) | China | Children attending school | 176 (41%) | 8-12 | Elementary school | Nonrandomized trial | Attitude and practice | intrinsic motivation for FVW intake; physical activity motivation; self-efficacy for FVW; FVW preferences; physical activity. | Children played *Escape from Diab*, a videogame based on social cognitive, self-determination, competence and elaboration-likelihood models (eg, identifying the problem in setting goals for vegetable intake, and finding the solutions). | No intervention | 8 -10 weeks | Digital game | Self-administered questionnaires were used at baseline, immediately after the game, and 8–10 weeks after the game (follow up). |
| 9 | Wengreen, 2021 (26) | USA | Children attending school | 1859 (47%) | 5-11 | Elementary School | RCT | Practice | FV consumption at lunchtime; skin carotenoids concentration | A 3 minute episode of the "*FIT Game*", a comic-book formatted cartoon, was shown during lunchtime in the school cafeteria. The episodes communicated daily whole-school vegetable-eating goals and illustrated the progress of the game's heroes when these goals were collectively met. | No intervention | 3 months | Video | Direct observation at baseline, after intervention (last 5 days) and after 3 months. |

Abbreviations: RCT, Randomized Controlled Trial; FV, fruit and vegetables; FVW, fruit, vegetables and water in two studies, while six of them were based on self-administered questionnaires, and a dietary recall tool was used in the other one. Post-intervention evaluation of the outcomes of interest was performed at different time points across the reports: in all cases, a post-intervention evaluation was carried out immediately after the intervention. Additionally, in five studies, a follow-up evaluation was performed at a time point ranging from 8 weeks to 4 months after the intervention. Overall, almost all the interventions tested were effective in promoting a healthy diet in school-aged children in the short term, compared to the control group, irrespectively of the type of intervention and age of the children. One study only, carried out among a selected sample of overweight children, showed no improvements in nutrition and health following the intervention. The complete results are reported in Table 2. Two studies (23,27) investigated overall nutrition knowledge after a videogame-based intervention: in the study by Froome et al., where nutrition knowledge was measured on a scale from 0 to 20 through a questionnaire, the intervention group went from 10.3 ± 2.9 to 13.5 ± 3.8 after the intervention, compared to the control group that went from 10.2 ± 3.1 to 10.4 ± 3.2 (p=0.001). Scores related to sub-groups knowledge (whole grain foods, vegetables and fruits, protein foods and drinks) are available in Table 2, and show a significant increase in all categories except for drinks, for which the score was already high at baseline (23). Gan et al. obtained similar results, evaluating both food groups and food frequencies knowledge on a scale from 0 to 15: for the experimental group, the score in nutrition knowledge statistically increased (p=0.001) from 9.08±3.48 to 11.42±3.25 after the intervention. A statistically significant improvement (p=0.001) was observed in the food frequency knowledge scores as well, that increased from 9.16±2.55 to 10.55±2.28 post-intervention. As for the control group, on the other hand, there was a significant (p=0.001) decline from the pre-test to the post-test score, both in terms of food group knowledge (from 9.55±3.72 to 8.66±3.82) and in terms of food frequency knowledge (from 9.67±2.79 to 9.22±2.75)(27). No follow-up data were collected in these two studies.

Five studies (22–26) investigated the changes in practices following intervention. Horne et al. (20) evaluated the percentage of fruit and vegetables servings consumed during snack time and lunchtime at baseline, during the intervention and at follow-up. The snack time fruit consumption was significantly higher post-intervention than at baseline (87% vs 75%) but declined at follow-up returning to baseline levels. In the control school there were no significant differences among the three study phases. Fruit and vegetable consumption at lunch time in the experimental group was significantly higher both at post-intervention and at follow-up compared to baseline, although fruit consumption declined at follow-up compared to post-intervention. In particular, children with the lowest scores at baseline in the experimental school showed the largest increase in fruit and vegetables consumption during intervention and follow-up. In the control school, fruit and vegetables consumption declined from baseline to follow-up. The study by Thompson et al. investigated the average number of fruit and vegetable servings consumed at baseline, post intervention and at follow-up. At baseline, children consumed an average of 1.8 servings per day. After the intervention, a significant increase in fruit and vegetables servings was observed both in the Action group (+ 0.72 servings, p=0.0001) and in the Coping group (+ 0.48 servings, p=0.001), although at follow-up only the Action group maintained these levels (+ 0.68 servings, p=0.0001). Wengreen et al. observed a significant increase in the amount of vegetables consumed by children attending the intervention schools (+10.66 g, p=0.001). Even though nearly half of the gains measured for vegetable consumption was lost at follow up, a moderate long-term increase above the baseline was observed to remain stable over time. The largest and longest lasting gains were measured in skin carotenoid concentrations, which were maintained at follow up (26).

Bell et al. observed that participants in the intervention group, after a 3-week intervention based on a digital game, had improved self-efficacy to eat, cook, and garden fruit and vegetables, compared with control participants (1.9% increase vs. 7.5% decrease, respectively; p=0.01). Nevertheless, no significant differences were observed between the intervention and control groups for any of the dietary intake measures or food preferences (22). Wang et al. also investigated self-efficacy for fruit, vegetables and water, as well as food preferences after a videogame-based intervention. A significant increase was observed in the intrinsic motivation for fruit (+1.6) and for water (+1.2), although they were not detected at follow up. The study by Sharma et al., based on a digital game intervention, highlighted a significant decrease in the amount of sugar consumed among children in the intervention group, compared with those in the control group (-4.9 g/1,000 kcal vs +5.61 g/1,000 kcal; P1/40.021). Compared with baseline, both intervention and control group children reported reduced energy intake post-intervention. However, the decreases in the control group were greater than those in the intervention group (24).

The study by Baranowski et al., carried out among overweight and obese children, observed no significant differences in fasting insulin, as well as in the intake of fruit, vegetables and water (21).

## Discussion

This systematic review provides a comprehensive summary of the available literature on the implementation of educational programs that use digital media for the promotion of healthy dietary habits among children. They were shown to be positively influenced by digital media interventions, increasing the amount of healthy food eaten during the day and adapting their food choices at lunch and snack time according to the lessons learned. Digital media, such as videogames and cartoons, are increasingly being used as teaching tools for school-aged children, and they represent a very easy and accessible tool that children are familiar and compliant with. Their use in the context of health promotion has been previously investigated, with results that vary depending on the tool used and on the outcomes measured (9,29).

From our analysis, serious videogames appear to be associated with a statistically significant increase in overall nutrition knowledge among children, especially in the short term. Similar results were obtained in previous studies among elementary school children, that showed an increase in food knowledge after playing *FoodRateMaster*, a serious videogame developed to increase the intake of healthy food and reduce the intake of ultra-processed food among children (30). These results, similarly to what our review shows, are based on data collected immediately after the intervention, and lack a follow-up. For this reason, further research is needed to evaluate whether the knowledge acquired through gameplay remains constant in the long term or it fades over time. In addition, further studies should investigate whether the acquired knowledge is put into practice, as this was not considered in the above-mentioned studies.

Our review shows that there is a growing trend of using digital tools to modify children's behaviors and attitudes. A significant increase in fruit and vegetables consumption was observed immediately after the intervention, both when cartoons and videos were used, and when videogames were implemented as teaching tools. The studies that included a long-term follow up evaluation (a few months after the intervention) showed that although fruit and vegetables consumption declined over time it remained above the baseline levels, thus confirming the effectiveness of the interventions compared to the control groups. Similar results were previously obtained by Baranowski et al. (17), who observed that 4$^{th}$ grade students who played a specifically-designed 10 session video game (*Squire's Quest!*) increased their fruit and vegetables consumption over a 5 weeks period by 1 serving more than the children who did not play the game. Similar results were obtained in other studies, that investigated the use of digital media tools to model children's behavior towards eating the recommended servings of fruit and vegetables per day (23,29,31).

Notably, only one study in our review highlighted no differences in eating behavior and attitudes following the intervention. However, the study population had been conveniently selected among overweight children attending a diabetes clinic. Therefore, the results might have been affected by the presence of other health conditions and risk factors related to diabetes. This also highlights the importance of early education and the promotion of a healthy diet since early childhood, before the onset of diseases such as type II Diabetes Mellitus, when it is easier to intervene and modify the disease progression (32).

**Table 2.** Main results of the included studies.

| N | First author and year [REF] | Pre-test | Post-test | Results |
|---|---|---|---|---|
| 1 | Baranowski, 2019 (21) | **Fasting insulin [mean (SD)]**<br>24.16 (18.5)<br>**Fruit servings per day [mean (SD)]**<br>1.09 (1.2)<br>**Vegetables servings per day [mean (SD)]**<br>0.95 (1.27)<br>**Sweetened beverages per day [mean (SD)]**<br>0.98 (0.73) | **Fasting insulin [mean (SD)]**<br>**post-intervention**<br>Intervention: 21.747 (2.01)<br>Control: 24.373 (1.712)<br>**at follow up**<br>Intervention: (21.268 (2.207)<br>Control: 22.381 (1.707)<br>**Fruit servings per day [mean (SD)]**<br>**post-intervention**<br>Intervention: –0.127 (0.096)<br>Control: –0.191 (0.082)<br>**at follow up**<br>Intervention: -0.303 (0.108)<br>Control: -0.351 (0.082)<br>**Vegetables servings per day [mean (SD)]**<br>**post-intervention**<br>Intervention: -0.303 (0.104)<br>Control: -0.422 (0.088)<br>**at follow up**<br>Intervention: -0.254 (0.116)<br>Control:-0.495 (0.089)<br>**Sweetened beverages per day [mean (SD)]**<br>**post-intervention**<br>Intervention: -0.222 (0.068)<br>Control: -0.107 (0.058)<br>**at follow up**<br>Intervention: -0.131 (0.076)<br>Control:-0.143 (0.058) | The combination of *Escape from Diab* and *Nanoswarm: Invasion from Inner Space* was not observed to impact the diabetes or obesity risk factors or risk-related behaviors of the participating overweight or obese children. No statistically significant differences were observed for any of the outcomes. |

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| 2 | Bell, 2018 (22) | **Total self-efficacy (mean, SE)**<br>Intervention: 3.08 (0.17)<br>Control: 3.20 (0.17)<br>**Total motivation (mean, SE)**<br>Intervention: 2.92 (0.18)<br>Control: 3.17 (0.19)<br>**Vegetables intake in cups/day (mean, SE)**<br>Intervention: 0.74 (0.44)<br>Control: 0.61 (0.43)<br>**Fruit intake in cups/day (mean, SE)**<br>Intervention:2.02 (0.51)<br>Control:1.65 (0.50) | **Total self-efficacy (mean, SD)**<br>Intervention: 3.14 (0.17)<br>Control: 2.96 (0.17)<br>**Total motivation (mean, SE)**<br>Intervention: 2.71 (0.21)<br>Control: 2.65 (0.22)<br>**Vegetables intake in cups/day (mean, SE)**<br>Intervention: 1.52 (0.41)<br>Control: 1.62 (0.40)<br>**Fruit intake in cups/day (mean, SE)**<br>Intervention: 3.19 (0.55)<br>Control: 3.12 (0.53) | Self-efficacy and motivation scores range from 1 to 4. After the 3-week intervention, participants in the intervention group had improved aggregated self-efficacy to eat, cook, and garden FV compared with control participants (1.9% increase vs. 7.5% decrease, respectively; P=0.01). Their mean self-efficacy to eat fruits and vegetables score increased 1.6%. The intervention group had a significantly lower decrease in total motivation to eat FV as compared with the control group, (decrease by 7.2% and 16.4%, respectively; P=0.03). There were no significant differences observed between the intervention and control groups for any of the dietary intake measures (vegetables, fruit, whole grains, fiber, total sugar, added sugar, energy from sugary beverages) or FV preferences. |
| 3 | Froome, 2020 (23) | **Overall Nutrition Knowledge Score**<br>Intervention = 10.3 ± 2.9<br>Control = 10.2 ± 3.1<br>**Whole Grain Foods Sub-score**<br>Intervention = 2.6 ± 1.3<br>Control = 2.5 ± 1.2<br>**Vegetables and Fruits Sub-score**<br>Intervention = 1.9 ± 1.0<br>Control = 2.2 ± 1.3<br>**Protein Foods Sub-score**<br>Intervention = 1.8 ± 1.0<br>Control = 1.7 ± 1.0<br>**Drinks Sub-score**<br>Intervention = 3.8 ± 1.0<br>Control = 3.8 ± 1.2 | **Overall Nutrition Knowledge Score**<br>Intervention = 13.5 ± 3.8<br>Control = 10.3 ± 3.2<br>**Whole Grain Foods Sub-score**<br>Intervention = 3.3 ± 1.4<br>Control = 2.7 ± 1.1<br>**Vegetables and Fruits Sub-score**<br>Intervention = 3.1 ± 1.5<br>Control = 2.2 ± 1.1<br>**Protein Foods Sub-score**<br>Intervention = 3.0 ± 1.6<br>Control = 1.9 ± 1.1<br>**Drinks Sub-score**<br>Intervention = 3.9 ± 0.74<br>Control = 3.5 ± 1.1 | During the intervention period, a statistically significant increase in overall nutrition knowledge was observed in the intervention group (+3.2), compared to the control group (+0.2, $p < 0.001$). A significant increases in nutrition knowledge was also observed in the intervention group, compared to the control group, related to sub-scores of Vegetables and Fruits (+1.2, $p < 0.001$), Protein Foods (+1.2, $p < 0.001$), and Whole Grain Foods (+0.7, p=0.040). No significant increase in knowledge was observed between the two groups in Drinks (p=0.206); however, baseline knowledge of Drinks was already relatively high in both the intervention (3.8 ± 1.0) and control (3.5 ± 1.2) groups. |
| 4 | Gan, 2019 (27) | **Food group knowledge:**<br>Control = 9.55;<br>Experimental=9.08;<br>**Food Frequency knowledge:**<br>Control= 9.67:<br>Experimental=9.16 | **Food group knowledge:**<br>Control = 8.66;<br>Experimental=11.42;<br>**Food Frequency knowledge:**<br>Control= 9.22:<br>Experimental=10.55 | In the experimental group, knowledge scores statistically increased from pre-test to post-test (34.1% of the change attributable to the intervention) and food frequency knowledge score significantly increased from pre-test to post-test (25.4% attributed to the intervention). In the control group, a decline in both food group and food frequency knowledge scores was observed from pre-test to post-test. |

(*Continued*)

**Table 2.** Main results of the included studies. (*Continued*)

| N | First author and year [REF] | Pre-test | Post-test | Results |
|---|---|---|---|---|
| 5 | Horne, 2004 (20) | **Snacktime fruit consumption at baseline (mean % of consumed):**<br>Experimental: 75%<br>Control: 65%<br>**FV consumption at lunchtime at baseline (mean % of FV consumed):**<br>Experimental:<br>5-7 y: F 20%; V 35%<br>7-11 y: F 47%; V 51%<br>Control:<br>5-7 y: F 11%; V 16%<br>7-11 y: F 20%; V 36% | **Snacktime fruit consumption (mean % of consumed) during intervention/baseline 2**<br>Experimental: 87%<br>Control: 61%<br>**at follow up**<br>Experimental: 76%<br>Control: 64%<br>**FV consumption at lunchtime (mean % of FV consumed) during intervention/baseline 2**<br>Experimental:<br>5-7 y: F 69%; V 55%<br>7-11 y: F 86%; V 74%<br>Control:<br>5-7 y: F 11%; V 6%<br>7-11 y: F 18%; V 20%<br>**at followup**<br>Experimental:<br>5-7 y: F 56%; V 53%<br>7-11 y: F 65%; V 63%<br>Control:<br>5-7 y: F 9%; V 10%<br>7-11 y: F 9%; V 23% | In the experimental school, fruit and vegetable consumption was significantly higher at intervention and at follow-up compared to baseline for all age groups (5-7 and 7-11 years old). Fruit consumption declined between intervention and follow up for all age groups, and vegetable consumption declined for children aged 7-11 years.<br>In the experimental school, children who ate the least at baseline (0-19%) showed the largest increases in consumption during intervention and follow-up.<br>In the control school, children who ate the least FV showed little change during the study.<br>There were also significant increases in FV consumption at home. |

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| 6 | Sharma, 2015 (24) | **Fruit servings per 1,000 kcal (mean ± SD)**<br>Intervention Group: 0.84 ± 0.67<br>Comparison Group: 0.81 ± 0.67<br>**Vegetables servings per 1,000 kcal (mean ± SD)**<br>Intervention Group: 0.56 ± 0.42<br>Comparison Group: 0.51 ± 0.33<br>**Sugars g/1,000 kcal (mean ± SD)**<br>Intervention Group: 55.35 ± 13.47<br>Comparison Group: 55.33 ± 16.94<br>**Energy kcal (mean ± SD)**<br>Intervention Group: 1,415.49 ± 412.02<br>Comparison Group: 1,632.51 ± 443.37<br>**Nutrition/Physical Activity Attitude (mean ± SD)**<br>Intervention Group: 6.04 ± 1.35<br>Comparison Group: 6.47 ± 1.12<br>**Nutrition/Physical Activity Knowledge (mean ± SD)**<br>Intervention Group: 5.29 ± 0.24<br>Comparison Group: 5.78 ± 0.21 | **Fruit servings per 1,000 kcal (mean ± SD)**<br>Intervention Group: 0.71 ± 0.67<br>Comparison Group: 0.79 ± 0.68<br>**Vegetables servings per 1,000 kcal (mean ± SD)**<br>Intervention Group: 0.50 ± 0.44<br>Comparison Group: 0.45 ± 0.37<br>**Sugars g/1,000 kcal (mean ± SD)**<br>Intervention Group: 50.45 ± 18.93<br>Comparison Group: 60.94 ± 15.97<br>**Energy kcal (mean ± SD)**<br>Intervention Group: 1,304.11 ± 571.60<br>Comparison Group: 1,331.46 ± 524.92<br>**Nutrition/Physical Activity Attitude (mean ± SD)**<br>Intervention Group: 6.89 ± 1.57<br>Comparison Group: 6.44 ± 1.16<br>**Nutrition/Physical Activity Knowledge (mean ± SD)**<br>Intervention Group: 5.19 ± 0.24<br>Comparison Group: 5.78 ± 1.91 | Results showed significant decreases post-intervention in the amount of sugar consumed among children in the intervention group, compared with those in the control group (-4.9 g/1,000 kcal vs +5.61 g/1,000 kcal; P1/40.021). Compared with baseline, both intervention and control group children reported reduced energy intake post-intervention. However, the decreases in the control group were greater than those in the intervention group.<br>Children in the intervention group showed significant increases on Nutrition/Physical Activity Attitude Scale post-intervention (+0.45 unit increase in scale score in the intervention group vs -0.03 unit decrease in scale score in the comparison group; P1/40.041) compared with those in the control group.<br>However, children in the intervention group also showed a decrease in their knowledge scores post-intervention compared with those in the control group. Results showed no significant effects of the intervention on computer learning attitude or nutrition self-efficacy. |
| 7 | Thompson, 2015 (25) | **FV consumption in number of servings (mean, SE)**<br>Control = 1.86 (0.04)<br>Action = 1.64 (0.04)<br>Coping = 1.83 (0.04)<br>Both A&C = 2.11 (0.04) | **FV consumption in number of servings post-intervention (mean, SE)**<br>Control = 2.20 (0.04)<br>Action = 2.37 (0.04)<br>Coping = 2.31 (0.04)<br>Both A&C = 2.28 (0.04)<br>**FV consumption in number of servings at follow-up (mean, SE)**<br>Control = 1.89 (0.04)<br>Action = 2.32 (0.04)<br>Coping = 2.11 (0.05)<br>Both A&C = 2.05 (0.04) | At first data collection, the Action and Coping groups had significant increases in FV intake compared to baseline. At 3-month follow-up, only the Action group maintained these increases. The Action group had almost a 50% increase in FV intake post-intervention (0.72 servings), and maintained this level at follow-up (0.68 servings) |

(*Continued*)

**Table 2.** Main results of the included studies. (*Continued*)

| N | First author and year [REF] | Pre-test | Post-test | Results |
|---|---|---|---|---|
| 8 | Wang, 2017 (28) | **Intrinsic motivation for fruit intake (mean, SD)**<br>Intervention: 24.0 (5.1)<br>Control: 24.7 (4.0)<br>**Intrinsic motivation for vegetable intake (mean, SD)**<br>Intervention: 17.4 (4.1)<br>Control: 18.5 (3.6)<br>**Intrinsic motivation for water intake (mean, SD)**<br>Intervention: 19.9 (4.6)<br>Control: 20.0 (3.4) | **Intrinsic motivation for fruit intake (mean, SD)**<br>**post-intervention**<br>Intervention: 24.0 (5.7)<br>Control: 23.2 (4.4)<br>**at follow up**<br>Intervention: 23.4 (5.2)<br>Control: 23.4 (5.1)<br>**Intrinsic motivation for vegetable intake (mean, SD)**<br>**post-intervention**<br>Intervention: 17.5 (4.9)<br>Control: 17.4 (3.9)<br>**at follow up**<br>Intervention: 17.1 (4.4)<br>Control: 17.0 (4.1)<br>**Intrinsic motivation for water intake (mean, SD)**<br>**post-intervention**<br>Intervention: 20.3 (4.3)<br>Control: 19.6 (3.7)<br>**at follow up**<br>Intervention: 19.3 (4.2)<br>Control: 19.0 (4.1) | After the intervention, there were significant adjusted changes (95% CI) between the treatment and control groups in intrinsic motivation for fruit: 1.6 (0.1–3.1 and intrinsic motivation for water: 1.2 (0.2–2.3), which increased in the treatment group but decreased in the control group. However, these significant adjusted changes were not detected at follow up. |

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| 9 | Wengreen, 2021 (26) | **Estimated group marginal means of fruit consumption in grams (mean, SEM)**<br>Intervention: 15.96 (3.94)<br>Control: 15.95 (3.91)<br>**Estimated group marginal means of vegetables consumption in grams (mean, SEM)**<br>Intervention: 42.90 (5.37)<br>Control: 46.29 (5.33)<br>**Estimated group marginal means of FV consumption in grams (mean, SEM)**<br>Intervention: 60.22 (11.38)<br>Control: 63.53 (11.35)<br>**Estimated group marginal means of skin carotenoids (mean, SEM)**<br>Intervention: 29,062 (588)<br>Control: 29,203 (534) | **Estimated group marginal means of fruit consumption in grams (mean, SEM) post-intervention**<br>Intervention: 26.61 (3.94)<br>Control: 17.38 (3.92)<br>**at follow up**<br>Intervention: 21.36 (3.94)<br>Control: 13.73 (3.92)<br>**Estimated group marginal means of vegetables consumption in grams (mean, SEM) post-intervention**<br>Intervention:58.57 (5.37)<br>Control: 42.24 (5.34)<br>**at follow up**<br>Intervention: 45.85 (5.37)<br>Control: 30.82 (5.34)<br>**Estimated group marginal means of FV consumption in grams (mean, SEM) post-intervention**<br>Intervention: 86.93 (11.39)<br>Control: 60.22 (11.36)<br>**at follow up**<br>Intervention: 66.01 (11.38)<br>Control: 43.74 (11.35)<br>**Estimated group marginal means of skin carotenoids (mean, SEM) post-intervention**<br>Intervention: 35,168 (596)<br>Control: 31,628 (543)<br>**at follow up**<br>Intervention: 34,012 (600)<br>Control: 30,912 (550) | At the end of the intervention phase, children attending the FIT Game schools were consuming significantly more vegetables than during baseline.<br>At follow-up assessment, nearly half of the gains measured for vegetable consumption among the children attending the FIT Game schools was lost, however a moderate long-term increase above the baseline was established. Conversely, a moderate long-term reduction in vegetable consumption was observed for children attending the Control schools.<br>When combined, the amount of FV consumed by children attending the FIT Game schools similarly exhibited a short-term increase, which was maintained at follow up.<br>The largest and longest lasting gains were measured in skin carotenoid concentrations, which were maintained at follow up. |

Abbreviations: Y, years; FV, fruit and vegetables; SE, standard error; SEM, standard error of the mean, SD, standard deviation.

Most of the studies included in our review were carried out in school settings, therefore highlighting the importance of a collaboration with schools to promote healthy habits among children. As children spend most of their time in class, schools are the ideal setting to positively influence children's quality of life and eating habits through targeted programs (33). In fact, school-based food and nutrition programs have been developed by The Food and Agriculture Organization (FAO) (34), to guide governments in the promotion and implementation of nutrition programs in school settings, to educate children and their parents on these issues.

The use of digital media for health promotion among children has been implemented also in other health fields, such as physical activity promotion (35) and skin cancer prevention (36), where digital media-based interventions were found to be more effective for increasing skin cancer knowledge and awareness as well as to increase adherence to physical activity, compared to teacher-led frontal lectures. Among the available digital media, videogames appear to be one of the most useful and appealing tools for health promotion among children, due to their engaging and interactive nature that allows to reach a wider share of children compared to traditional teaching strategies (9).

Some limitations must be taken into consideration for this review. First of all, only a limited number of studies were included: in fact, several studies were excluded from our review due to their wider age range of participants and the lack of results stratification by age. Another potential limitation is the lack of follow-up in most of the studies included, therefore data are limited to the immediate impact of digital media on children's nutrition knowledge and behavior. Nevertheless, this could be used as a starting point for future and more prolonged interventions. Despite these potential limitations, our work has several strengths and offers inputs for further research. In particular, having included only experimental studies provides strong and valuable evidence on this issue. In addition, to our knowledge this is the first systematic review investigating the impact of digital media tools on healthy nutrition promotion among children.

## Conclusions

Digital tools are increasingly becoming an important part of our society, and children are exposed to them starting from a very early age. Therefore, it is important to learn how to use them for the promotion of healthy habits among children. It is particularly important to target children for these purposes, as learning at a young age sets the ground for future habits and is key for the development of a healthy lifestyle throughout adulthood. Videogames and cartoons were shown to be extremely valuable tools to stimulate children to improve their dietary habits, convoying important messages through child-friendly communication. However, as the impact of these interventions on children's eating behavior appears to fade after a few months, it is important to develop further teaching strategies to maintain and strengthen the acquired knowledge over time. For this purpose, reinforcement methods (i.e. reward systems, gadgets, follow-up lessons) might be considered to improve adherence, and to encourage children to continue applying the lessons learned. In addition, families should be more involved in the process, as health education cannot be limited to school settings, but should be maintained within the household (i.e., through additional material or reminders (37)). In this context, children play an important role as they can convoy important messages to their parents, thus influencing family habits as well.

The findings of this systematic review will provide useful information that could be used to set the grounds for the development of future teaching strategies targeting children in the context of health promotion, not only in the field of nutrition.

**Ethic Committee:** not applicable

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